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**NUCLEAR POWER PRODUCTION:  
THE FINANCIAL COSTS**

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**November 1993**



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## **NUCLEAR POWER PRODUCTION: THE FINANCIAL COSTS**

### **INTRODUCTION**

For many years, the Canadian nuclear industry has prided itself on its ability to provide safe, reliable and low-cost electricity to consumers. While nuclear power has indeed proved to be a relatively safe generator of electricity, its performance with respect to reliability and cost has declined noticeably in recent years.

This paper documents the deteriorating cost performance of the industry, in comparison with that of its traditional competitor in power generation. It also breaks down the total costs into its component parts, assessing the key factors underlying the trends that are worsening the competitive position of the industry: a rise in initial capital costs, unanticipated technical difficulties resulting in additional capital costs, and the increasing operating expenses associated with poorer-than-expected reactor performance.

### **COST PERFORMANCE**

There are a number of ways of measuring the costs of various forms of power generation, but Canadian utilities tend to use two approaches. The most straightforward of these is to calculate the total costs attributable to generation by a specific source during any given year, and then to divide this figure by the amount of electricity produced, expressed in kilowatt-hours (kWh). The result is the average unit energy cost for the year in question, for that fuel source.

The energy option that has traditionally provided the most direct competition with nuclear power plants is the fossil fuel-fired station, with coal as the usual fuel. As Table 1

indicates, Ontario's nuclear production enjoyed a sizeable cost advantage over fossil fuels as recently as the mid-1980s, with the gap in unit energy cost a hefty 35% in 1986. Since then, however, the margin has diminished, to the point where the cost advantage is now under 5%.

Table 1

Cost Advantage of Nuclear over Fossil Fuels in Ontario,  
1980-1992  
(cents/kWh)

Year	Fossil	Nuclear*	% Cost Advantage
1980	2.9	1.4	52
1985	4.0	2.8	31
1986	4.7	3.0	35
1987	4.0	3.2	21
1988	3.7	3.2	15
1989	3.7	3.4	8
1990	4.7	4.2	9
1991	4.7	4.3	9
1992	5.0	4.8	4

\* Nuclear costs include an allowance for irradiated fuel interim storage, disposal cost and for plant decommissioning.

Source: Ontario Hydro, *Annual Report 1992*, p. 48; Ernst and Young, *The Economic Effects of the Canadian Nuclear Industry*, October 1993, Exhibit 2.14, p. 32.

In New Brunswick, the situation is quite different, in that the traditional cost advantage that the Point Lepreau reactor enjoyed over coal is increasing. In that province, nuclear power remains somewhat uncompetitive with oil, with the gap between them rising slightly in recent years.<sup>(1)</sup>

Another way to consider nuclear costs is to examine them over the expected lifespan of the power plant, and to discount these future costs back to the present. Using this costing method, one arrives at the levelized unit energy cost (LUEC) of electricity generation,

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(1) Ernst and Young, *The Economic Effects of the Canadian Nuclear Industry*, October 1993, p. 33.

which represents the constant sum of money to be charged for each kWh of electricity produced through the lifetime of the facility. The LUEC is useful because it reduces the lifetime costs of electricity generation to one figure.

Generating a figure for the LUEC is typically the costing methodology used by utility planners considering the long-term costs of different electricity-generating options. Ontario Hydro's LUEC analysis in 1989 concluded that the nuclear option provided a 0.8 cents/kWh (in 1989\$) advantage over a conventional steam-cycle U.S. coal-fuelled station.<sup>(2)</sup> It should be noted, however, that the analysis assumed an average capacity factor of 80% over the lifetime of the plant; in retrospect, this is quite an ambitious assumption.

When calculating a value for the LUEC, it is important to keep in mind that the costs of nuclear power fluctuate substantially depending upon the discount rate used, the length of plant life chosen, and the assumption made regarding power plant reliability. Labour and unforeseen repair costs, as well as the cost of capital, should also be considered.

A low discount rate would have a positive influence on the choice of plant, given the tremendous reliance of nuclear plant operators on debt financing. Normally, the discount rate chosen should correspond roughly with the real rate of interest (i.e., the rate of interest above inflation).

Given that nuclear power plants experience very high initial capital costs and significantly lower operating and fuel costs, the life span of a facility is an important factor in measuring the plant's worth. Essentially, the longer the plant can remain operational, the lower the real cost of the power.

Once constructed, nuclear plants must perform reliably; that is, they must generate power consistently and without interruption. For years, the CANDU reactor registered the highest efficiency rating (or load factor) of any reactor in the world, operating full out 80% to 90% of the time. For the domestic utilities, this excellent performance achieved translated directly into lower operating and maintenance costs.

CANDU's success in this regard began to erode when unanticipated cracks began to appear in pressure tubes at Ontario Hydro's Pickering 2 nuclear site in 1983. Other

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(2) Ontario Hydro, *Providing the Balance of Power*, Demand/Supply Plan Report, 1989, p. 6-11.

"accidents" have occurred at other sites as the reactors have aged; as a result, the utility's nuclear stations have not performed at the forecasted 80% capacity level for the past decade.

Canada's nuclear power efficiency performance is, at best, now "middle of the pack" when compared with that of other nuclear producers. As the international comparison of load factors in Table 2 demonstrates, the average Canadian reactor now runs for only about 65% of the time, and the historical capacity average (lifetime load factor) is 74%, down from 79% in 1989. These results have been well below expectations.

Table 2

Nuclear Power Performance Ratings, by Country\*  
(to 30 September 1992)

Country	No. Reactors	Annual Load Factor (%)	Lifetime Load Factor (%)	Capacity MWe
Belgium	7	84.6	81.0	5,751
Bulgaria	6	35.5	61.9	3,760
Canada	19	65.3	73.7	13,904
Czechoslovakia	8	76.3	77.5	3,542
Finland	4	89.3	83.8	2,400
France	55	62.8	63.1	59,104
Germany	21	75.2	72.0	23,814
Hungary	4	87.4	84.3	1,840
India	7	39.7	42.2	1,565
Japan	42	72.3	68.9	33,399
South Korea	9	83.4	74.6	7,757.7
Spain	9	82.9	74.7	7,388
Sweden	12	76.0	70.6	10,422
Switzerland	5	84.1	81.5	3,109
Taiwan	6	76.3	67.2	5,144
United Kingdom	29	52.5	50.8	14,204.4
United States	109	68.5	61.5	106,742.6

\* The data represent country averages, for countries with four or more operating reactors 150 MW Gross or over.

Source: Atomic Energy of Canada Ltd., *Nuclear Sector Focus*, 1993, Table 6.

Another indication of the decline in reliability is the relative standing of Canadian reactors. In 1988, six of the ten most reliable reactors in the world, as measured by the lifetime load factor, were CANDUs; this number has now been reduced by one-half.<sup>(3)</sup>

## COST COMPONENTS

Essentially, the total cost of nuclear power can be broken down into three components: capital costs, including the costs of decommissioning a reactor at the end of its lifespan; operating and maintenance costs; and fuel costs. These costs represent the direct costs of nuclear power generation to the utility. The social costs of nuclear power generation, such as subsidies for R&D, environmental costs and the cost of regulation can also be considered, but are treated as external to the utility in question.

Proponents of nuclear power production have generally promoted this energy option citing its competitive advantage over other electricity-generating fuels as a result of its low fuel costs, and its perceived ability to service high capital costs through its long operating span. Since fuel costs as a function of total nuclear costs have remained low in recent years, it is the ability of nuclear power utilities such as Ontario Hydro to control capital and operating costs that has become a source of concern.

### A. Capital Costs

Globally, capital costs make up over one-half of the total lifetime costs of a nuclear plant; they represent 25-35% of the lifetime costs of a comparable coal-fired power plant, and even less of those of a gas-fired facility.<sup>(4)</sup> Capital costs are incurred primarily in the acquisition phase (see Figure 1), and interest payments during the initial construction period have historically been the highest single item of expenditure in the capital cost account. It is therefore important to construct the power plants without undue delay, and to limit the interest costs of servicing the debt assumed to pay for the plant.

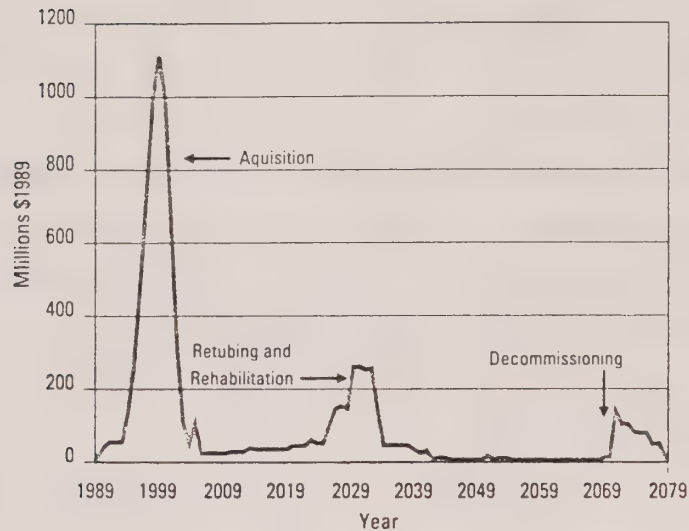
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(3) Ernst and Young (1993), p. 16.

(4) "Nuclear Power: Losing its Charm," *The Economist*, 21 November 1992, p. 21. Capital costs as a share of total costs for Ontario Hydro's reactors, in the order of 70%, have exceeded global averages.

Figure 1

### Life Cycle Capital Costs of a Nuclear Plant



Source: Ontario Hydro, *Providing the Balance of Power*, Demand/Supply Plan Report, 1989, Figure 6-2, p. 6-5.

Additional capital costs must also be factored in during the operating phase of the nuclear facility (primarily retubing) and the post-operation stage (decommissioning). It is vital that the plant's performance be reliable over its lifespan, so as to minimize these additional capital costs, to provide the revenues with which to service the debt, and to cover anticipated decommissioning costs.

Regrettably, the nuclear industry has been increasingly plagued by cost overruns at the construction stage. One analyst has calculated the final completion cost of the Darlington power plant in Ontario to be 340% of the original estimate, even after accounting for inflation. That same expert has also stated that all Ontario Hydro's reactors, with the exception of the first four Pickering units, had overruns exceeding 100%<sup>(5)</sup> In 1988, the House of Commons

(5) Thomas Adams, "Ontario Hydro's Fatal Condition: Implications for Canadian Public Policy," *Canadian Business Economics*, Spring 1993, p. 20.

Standing Committee on Energy, Mines and Resources also pointed to initial capital cost excesses, at the Pickering B and Bruce B stations, and at Point Lepreau in New Brunswick.<sup>(6)</sup>

Not only do these projects suffer from the inevitable financial risks associated with generally expensive major capital projects, they have also been influenced by the complex nature of plant design and to some extent by public concerns over safety. The increased cost of new generating facilities has been the prime cause of the large increases in electricity rates in Ontario in recent years.<sup>(7)</sup>

It is also of concern that the expected life cycles of certain Ontario Hydro nuclear facilities are not developing without the need for substantial new capital investments to respond to unforeseen technical problems. In the case of both Pickering A and Bruce A nuclear stations, decreasing generating capability became apparent after an initial eight-to-ten-year period. More specifically, there was an early deterioration of pressure tubes in certain reactor units (e.g., Pickering units 3 and 4), which resulted in retubing costs of \$461 million.<sup>(8)</sup> Pressure tube ruptures also had to be repaired at Pickering Unit 2 in 1983 and Bruce Unit 2 in 1986. The utility's four-reactor \$13.5-billion nuclear facility at Darlington has also experienced a number of serious technical problems, particularly at Unit 2, which was shut down for much of 1991 as a result of damage to fuel bundles. The increased costs involved in improving the performance of existing nuclear stations have also contributed to recent rate increases at Ontario Hydro.

On the positive side, these capital investments can help restore the reactors to almost new condition, and therefore improve their reliability and significantly reduce future inspection, analysis and licensing costs. The improved performance of the nuclear power units at the Pickering A station after retubing is evidence of this.<sup>(9)</sup> It will be interesting to observe

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(6) House of Commons Standing Committee on Energy, Mines and Resources, Tenth Report, *Nuclear Energy: Unmasking the Mystery*, 2nd Session, 33rd Parliament, August 1988, p. 130. Actual figures versus estimated costs were identified as follows: Pickering B \$3.9 billion vs. \$1.6 billion; Bruce B \$6.0 billion vs. \$3.9 billion; and Point Lepreau \$1.4 billion vs. \$0.5 billion.

(7) Ontario Hydro, "Let's Give Tomorrow a Hand," *Annual Report 1992, 1993*, p. 14.

(8) It had always been anticipated that pressure tubes would need replacement during the reactor's life span; however, the timing of these capital investments has been brought forward.

(9) Ernst and Young (1993), p. 35.

Ontario's reliability performance in 1993 and beyond as the repairs to certain older generating stations and to Darlington begin to realize returns.

Finally, another factor in any consideration of capital costs is the expense of plant decommissioning. Since no commercial nuclear reactor has yet been fully decommissioned, it is still difficult to know what the precise costs of doing this will be; one can only rely on the estimates. A recent OECD study on the economics and technology of nuclear power suggests that the decommissioning costs for large reactors can be quite high in absolute terms, in excess of \$100 million. Such costs would, however, represent an extremely minor component of total power generation costs.<sup>(10)</sup>

The domestic industry is confident that future decommissioning (and waste disposal) costs will be manageable, and have provided for this eventuality in its financial statements. While funds have been earmarked for decommissioning in an accounting or bookkeeping sense, however, no moneys have actually been set aside. Instead, utilities invest these funds in their operations, anticipating that these expenses will be covered by future income.

## **B. Operations and Maintenance (O&M) Costs**

Ontario Hydro's total operating costs have increased by over 40% in the past five years, to a total of almost \$7.5 billion in 1992.<sup>(11)</sup> The bulk of this increase can be attributed to two factors: increased costs to place new facilities in service (e.g., Darlington) and the costs of maintaining and restoring aging generation and transmission facilities.

In the nuclear area specifically, the utility's deteriorating reliability has caused an unanticipated increase in O&M costs. In fact, the average annual rate of growth of nuclear-related O&M costs has, since 1988, exceeded that of capital costs (39% vs. 30%).

As mentioned above, utilities were counting on low O&M costs over a long period in order to offset high construction and retubing costs. In reality, however, output has fallen as the reliability of the reactors has come into question, and operating costs have escalated.

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(10) Nuclear Energy Agency, *Nuclear Power Economics and Technology: An Overview*, Organisation for Economic Co-operation and Development, Paris, 1992, p. 49.

(11) Ontario Hydro (1993), p. 23.

The Canadian nuclear industry has routinely underestimated the repair costs of operating reactors as owners have faced expensive, unanticipated repairs.

### C. Fuel Costs

Whereas rapid increases in capital costs have posed a serious problem for the industry, the nuclear option continues to be economically superior in terms of its low fuel costs for operating electric power plants. Since the mid-1970s, nuclear-generated electricity has recorded the lowest unit fuel cost of all electrical options. In 1990, for example, the cost of uranium totalled 4.88 mills per kWh, compared with 5.87 mills for western coal, 21.67 mills for natural gas, 22.83 mills for eastern coal, and 32.93 mills for petroleum.<sup>(12)</sup>

Moreover, the cost of the uranium input has declined in recent years (in real terms) as uranium prices have fallen. On the other hand, prices of competing fuels such as natural gas and coal have declined even further, at least throughout the 1980s. This reality, coupled with the fact that fuel costs are a bigger share of total costs for these other fuels than for uranium, has rendered nuclear's competitive position somewhat less advantageous.

The costs of processed fuel storage and waste disposal are at best uncertain; however, a recent OECD study discloses that the costs of the back-end of the nuclear fuel cycle are not expected to exceed 10% of the overall fuel cost.<sup>(13)</sup> Ontario Hydro adds a surcharge to normal annual generation costs to cover these end-of-the-cycle requirements.

### D. Social Costs

Apart from the internal private costs for producing firms, energy activity has also resulted in financial costs for society as a whole. Nuclear power is no exception. Over the years, for example, the taxpayers of Canada have funded an extensive program of nuclear R&D. The cost of previous and ongoing research is not taken into account when calculating the cost of nuclear power. While research does not represent a significant share of the combined lifetime costs of nuclear power production, this subsidy to the industry is paid for by Canadians. A

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(12) Energy, Mines and Resources Canada, *Electric Power in Canada 1991*, Table 11.2, p. 81.

(13) Nuclear Energy Agency (1992), p. 48.

recent study of the domestic nuclear industry has calculated the cost to taxpayers over a 40-year period (1952-53 to 1992-93) to be approximately \$3.7 billion in as-spent dollars.<sup>(14)</sup>

Through their tax dollars, Canadian taxpayers have also supported prototype and commercial reactors, heavy water plants, the high costs of regulating the industry, and the exemption of provincial utilities from federal income taxation. Loan guarantees provided to Ontario Hydro by the provincial government to cover the high capital costs of the industry have lowered the cost of debt servicing. Moreover, it has been argued by critics of the domestic nuclear program that the federal government currently subsidizes the nuclear industry by limiting to a mere \$75 million the liability of the owners of a power generating company in the case of an accident.<sup>(15)</sup> Since this limit on nuclear liability came into effect in 1976, its value has been eroded by the effects of inflation. Moreover, in the future, the costs of nuclear waste disposal and plant decommissioning may not be borne entirely by the utilities, but rather by society in general.

This is not to imply that the nuclear industry is unique within the energy sector in terms of incurring financial costs for society; external costs, although of a different variety, can also be found for competing energy industries. Even so, those associated with the nuclear industry are sufficiently important to merit discussion.

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(14) Ernst and Young (1993), Exhibit 2.11.

(15) A move to impose full liability on owners would undoubtedly alter the economics of nuclear power, through increased insurance costs.

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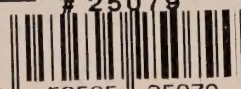






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